THE WEATHER AND CIRCULATION OF APRIL 1959

Including the Role Played by an Index Cycle

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1. INTRODUCTION

April 1959 was characterized by a lack of severe local storminess throughout most of the United States. A similar condition prevailed in April of 1958 [1], in sharp contrast to the stormy April of 1957 [2] when a record number of tornadoes was observed. From the northern Rocky Mountain States southeastward to the Gulf States, temperatures averaged below the seasonal normals, while west of the Rockies and in the northeastern third of the Nation the weather was generally mild. The long period of unusual warmth continued along the California coast, with new April temperature records being established. Precipitation continued deficient in the northern Great Plains and upper Mississippi Valley, with some areas reporting the least amount of record for the period January to April. Subnormal amounts of precipitation also fell in parts of the Southwest, thus continuing the dryness of the winter season.

Despite the fact that few monthly records were established during April, pronounced changes in weather and circulation did occur. These changes can be related to a strong index cycle.

2. MONTHLY MEAN CIRCULATION

The average circulation pattern for April 1959 (fig. 1) was one of relatively fast westerly flow with wave systems of small amplitude around the entire Northern Hemisphere. Over the Western Hemisphere the zonal index, a measure of the net geostrophic west wind between latitudes 55° N. and 35° N., averaged 0.8 m.p.s. above the April normal. This continues the period of above normal values of this index that began in February 1959 [3]. At higher latitudes the polar westerlies (55° N.–70° N.) were 0.8 m.p.s. below normal, mostly as a result of blocking over eastern Canada. The subtropical westerlies (20° N.–35° N.) also averaged slightly below their normal value.

Only one full-latitude trough was observed during April, from the Bering Sea southward to just west of the Hawaiian Islands (fig. 1). Nearly-full-latitude troughs were observed along the eastern Asiatic coast and over eastern North America. The latter trough, along with a strong ridge over the Pacific coast, controlled much of the weather in the United States. Blocking in Scandinavia was associated with a middle- and low-latitude trough extending from eastern Europe to North Africa. The latter two features of the planetary circulation resulted in confluence over central Asia, where a narrow band of above normal wind speeds prevailed at 700 mb.

In the Pacific the zone of maximum wind speed at 700 mb. was found just east of the Japanese Islands (fig. 2A), somewhat farther west than normal. This position can be related to the westward displacement of the normal trough near the Asiatic coast [4] and to the appearance of a mean ridge in the western Pacific (fig. 1).

Across North America the major trough-ridge system was also displaced west of its position on the normal map [4], though wind speeds at 700 mb. over the United States did not depart significantly from their normal values (fig. 2B). As a result the observed jet axes at 700 mb. bore a strong resemblance to their normal counterparts (not shown). Fast westerly flow prevailed across the Atlantic, where wind speeds were above normal in a narrow band centered around the 45th parallel (fig. 2). Greatest departures were observed in the eastern Atlantic, where speeds were as much as 6 m.p.s. above normal. Here also was found the center of greatest height anomaly over the Western Hemisphere, some 260 ft. below normal (fig. 1). Mean sea level pressures in this area were as much as 8 mb. below normal. A well-defined jet axis existed across the Atlantic (fig. 2A). This current split into two branches as it approached Europe, one branch passing northward through Scandinavia, the other southward across North Africa. Here again the configuration of the primary jet axes strongly resembled the normal.

The greatest anomaly of 700-mb. height, −310 ft., was associated with an extensive center of action over northern Asia (fig. 1). Very cold air, as much as 10° C. below normal in the layer from 1,000 mb. to 700 mb., accompanied this center. Because of this extreme cold, sea level pressures, on the average, were at most only 4 mb. below normal.

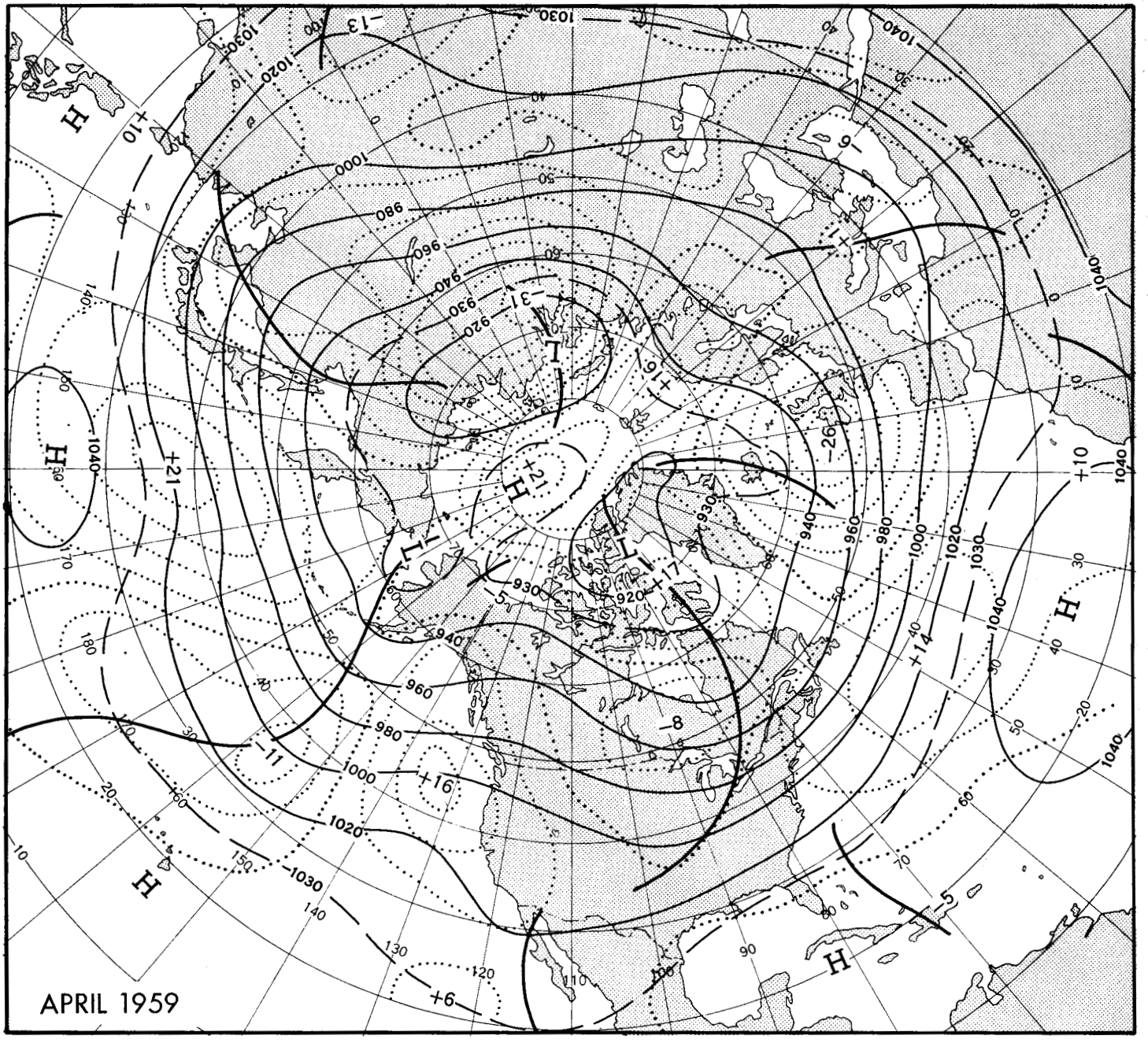

FIGURE 1.—Mean 700-mb. height contours (solid) and departures from normal (dotted) (both in tens of feet) for April 1959. Principal circulation features influencing weather in the United States were stronger than normal ridge near the west coast and trough in eastern North America.

3. AVERAGE UNITED STATES WEATHER RELATED TO THE MEAN CIRCULATION

Charts depicting the departure of average surface temperature from normal and the total precipitation for April are shown in figure 3. In addition, figure 4 gives the percentage of normal precipitation for April and for the period December 1958–April 1959.

A warm dry regime prevailed quite generally west of the Continental Divide, with temperature departures of

TABLE 1.—*Selected California cities which reported unusual warmth during April 1959*

City	Mean temperature (° F.)	Anomaly (° F.)	Years of record	Remarks
Burbank	65.0	+4.5	28	Warmest April of record.
Los Angeles (city office)	66.2	+4.7	82	
Los Angeles (airport)	65.4	+6.2	28	
San Diego	64.7	+4.2	87	
San Francisco (airport)	59.8	+5.7	31	
Oakland	60.1	+4.5	31	
Sacramento	64.3	+5.1	82	2d warmest April of record.
Blue Canyon	51.8	+6.7	54	

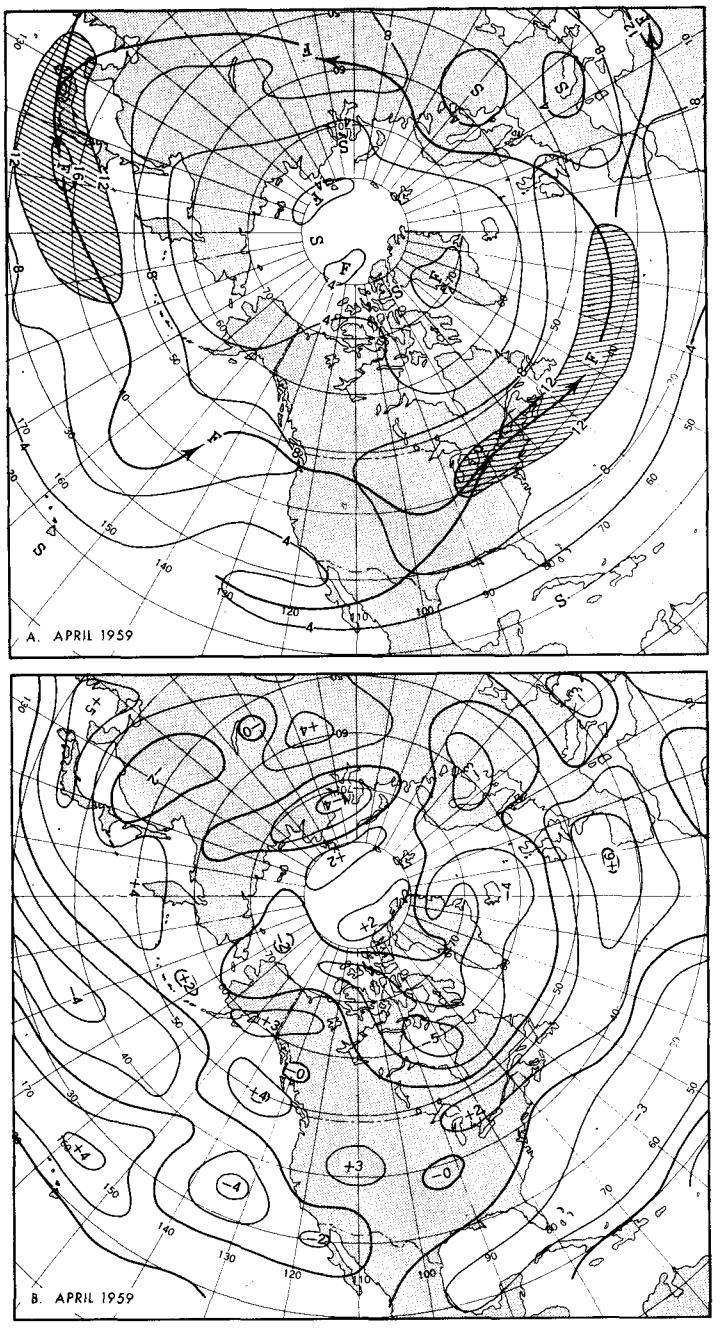

FIGURE 2.—(A) Mean 700-mb. isotachs and (B) departure from normal wind speed (both in meters per second) for April 1959. Solid arrows in (A) indicate primary axes of westerly jet, with speeds greater than 12 m.p.s. stippled. Jet maxima were located near the Asiatic coast and over the Atlantic Ocean, while wind speeds were close to normal over most of the United States.

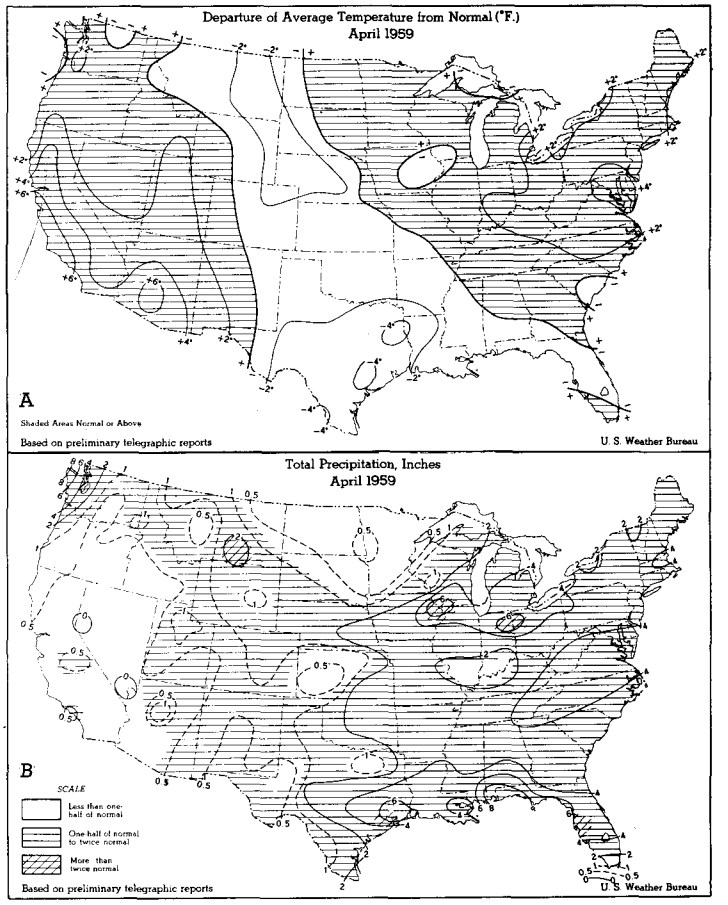

FIGURE 3.—(A) Departure of average surface temperature (° F.) from normal and (B) total precipitation (inches) for April 1959. Features were the record warmth along the California coast and continued precipitation deficiency in the northern Plains. (From *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 18, May 4, 1959.)

as much as 6° F. in portions of Arizona and California (fig. 3A). In the latter State the warmth was of a record-breaking nature, thus continuing the long period of unusual warmth which began during winter 1957–1958. Table 1 shows a representative list of cities in California where heat records were approached or established. Precipitation was markedly deficient throughout much of the Far West, with approximately 25 percent of normal in California, Nevada, southern Idaho, and western Arizona (fig. 4A). Since December 1958 a vast area from central Texas to southern California has received less than half its normal amount of precipitation (fig. 4B). Amarillo and Wichita Falls, Tex., have been drier than normal for 9 consecutive months. Abundant sunshine accompanied the warm, dry weather, with Ely, Nev., and Sacramento, Calif., experiencing their sunniest April on record.

Anticyclonic conditions associated with a stronger than normal upper-level ridge near the west coast (fig. 1) were largely responsible for this warm, dry regime. Moreover, northerly anomalous flow tended to inhibit precipitation. In California stronger than normal northeasterly flow resulted in foehn warming, thus contributing further to the unusual warmth along the coast.

Temperatures averaged below normal in the Great Plains, the lower Mississippi Valley, and along the Gulf coast (fig. 3A). Greatest departures were observed in southeastern Texas and northwestern Louisiana, where

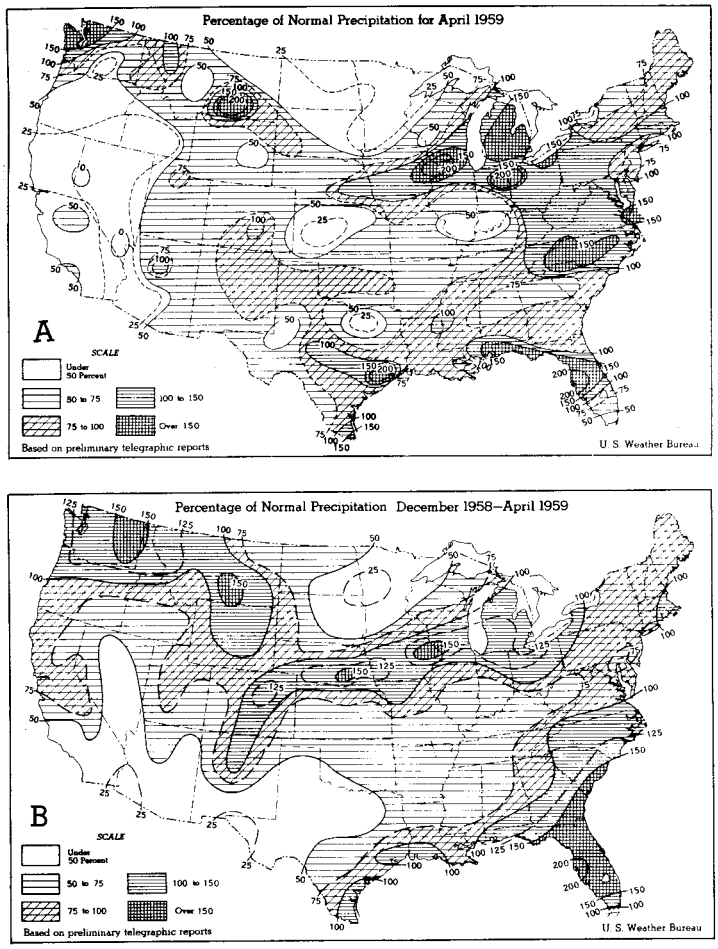

FIGURE 4.—Percentage of normal precipitation for (A) April 1959 and (B) December 1958–April 1959. Note prolonged period of dryness in Southwest and northern Plains. (From *Weekly Weather and Crop Bulletin National Summary*, vol. XLVI, No. 18, May 4, 1959.)

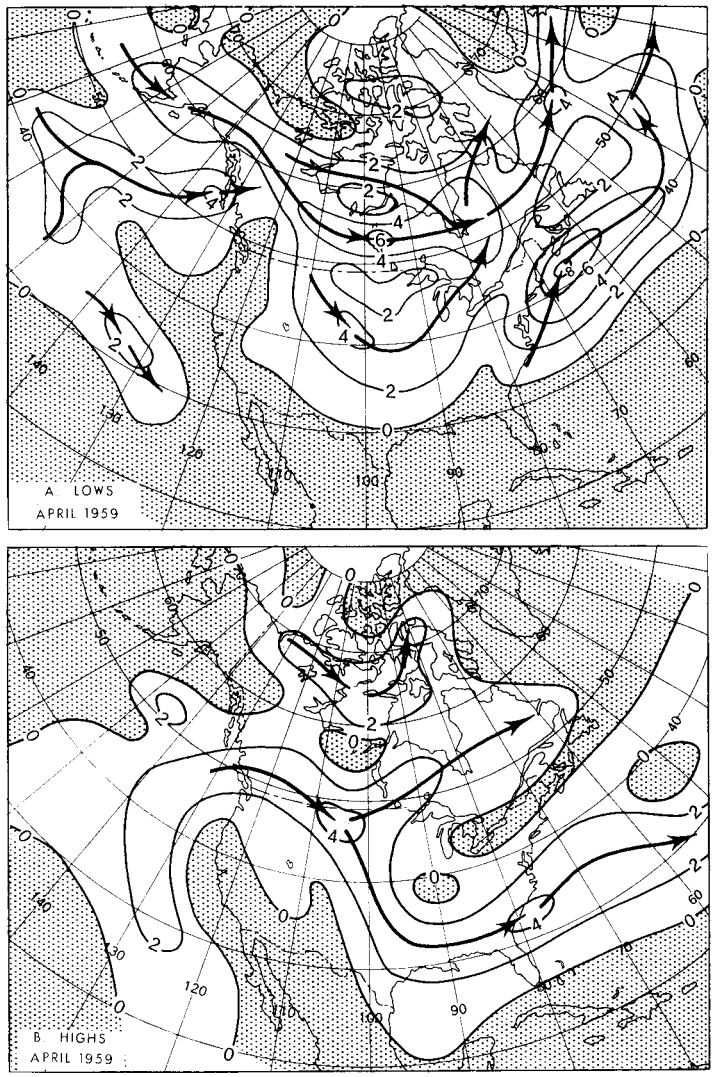

FIGURE 5.—Frequency of (A) cyclone passages and (B) anticyclone passages (within equal area boxes of 66,000 n. mi.^{2} [6]) during April 1959. Primary tracks are indicated by solid arrows. Cyclone tracks in the United States were rather well related to the precipitation pattern, while the major anticyclone track was associated with cool weather in mid-United States.

temperatures were as much as 4° F. below normal. Most of this coolness can be related to polar air masses associated with anticyclones steered southward by stronger than normal northerly flow (fig. 1) along a well-defined primary track (fig. 5B).

Precipitation in the Great Plains and Mississippi Valley was generally well below normal (fig. 4A). A large area in the Dakotas and Minnesota received less than a half inch of moisture during April (fig. 3B). In that area the total precipitation for the 5-month period December 1958 to April 1959 has been much below normal (fig. 4B). At Duluth and St. Cloud, Minn., with 1.34 and 1.22 inches for the period January to April, it was the driest such period in their respective 88 and 54 years of record. At Huron, S. Dak., this same period was the second driest in 77 years.

Most of this precipitation deficiency in the Plains States and Mississippi Valley appears to have been a function of stronger than normal northwesterly flow to the rear of the mean trough in eastern North America (fig. 1). In addition, the primary storm tracks passed both north and south of the northern Great Plains and upper Mississippi Valley (fig. 5A). Along the southern track a narrow band of heavier precipitation extended from southern Montana through Nebraska to the lower Lakes Region (figs. 3B and 4A). In Wyoming and Colorado, precipitation was largely in the form of snow which occurred during two periods and brought the month's total snowfall generally well above average. Heavy precipitation also occurred along the Texas coast, mostly as the result of overrunning of cool polar air masses in southwesterly flow aloft.

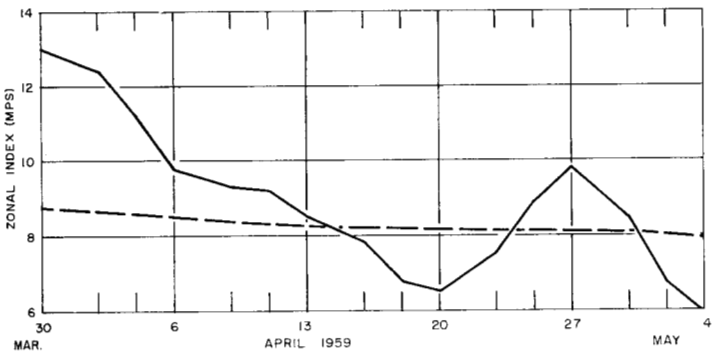

FIGURE 6.—Time variation of speed of 700-mb. westerlies averaged over the Western Hemisphere between latitudes 35° N. and 55° N. Solid line connects 5-day mean index values (plotted at middle of period and computed thrice weekly), while dashed line gives the corresponding normal. Index cycle was a prominent feature of the circulation.

Above-normal temperatures prevailed quite generally east of a line from the central Dakotas to southern Georgia, with greatest departures in the Middle Atlantic States (fig. 3A). This unseasonable warmth was associated with above normal heights and southerly anomalous flow at 700 mb. (fig. 1) and at sea level (chart XI in [5]). The heaviest precipitation in the United States occurred rather generally throughout the eastern half of the Nation (fig. 3B) and was related primarily to the mean trough (fig. 1). At sea level two principal storm tracks, one across the Great Lakes and the other along the Atlantic coast (fig. 5A), contributed to this precipitation. Lakeland, Fla., reported an alltime April precipitation record of 8.48 inches, with the January–April total of 28.00 inches also a record for the period. A relatively short distance away, Key West, Fla., with a long station record, received no measurable precipitation, also an April record. This extreme difference between Lakeland and Key West cannot readily be explained by large-scale, time-averaged charts.

4. WEEK-TO-WEEK VARIABILITY

Figure 6 shows the time variation of the temperate-latitude 5-day mean zonal index for April 1959. The complete index cycle portrayed here was accompanied by pronounced changes in weather and circulation. These changes will be described, using a series of 5-day mean 700-mb. charts centered 1 week apart, along with accompanying charts of weekly temperature departure from normal and total precipitation (figs. 7 to 11).

WEEK ENDING APRIL 5

The month began with the westerlies at their greatest strength, some 4 m.p.s. above normal (fig. 6), with fast flow predominating over nearly the entire hemisphere (fig. 7A). The only exception to this strong circumpolar whirl was in Europe, where a strong blocking ridge, accompanied by a Low in the Mediterranean, resulted in a

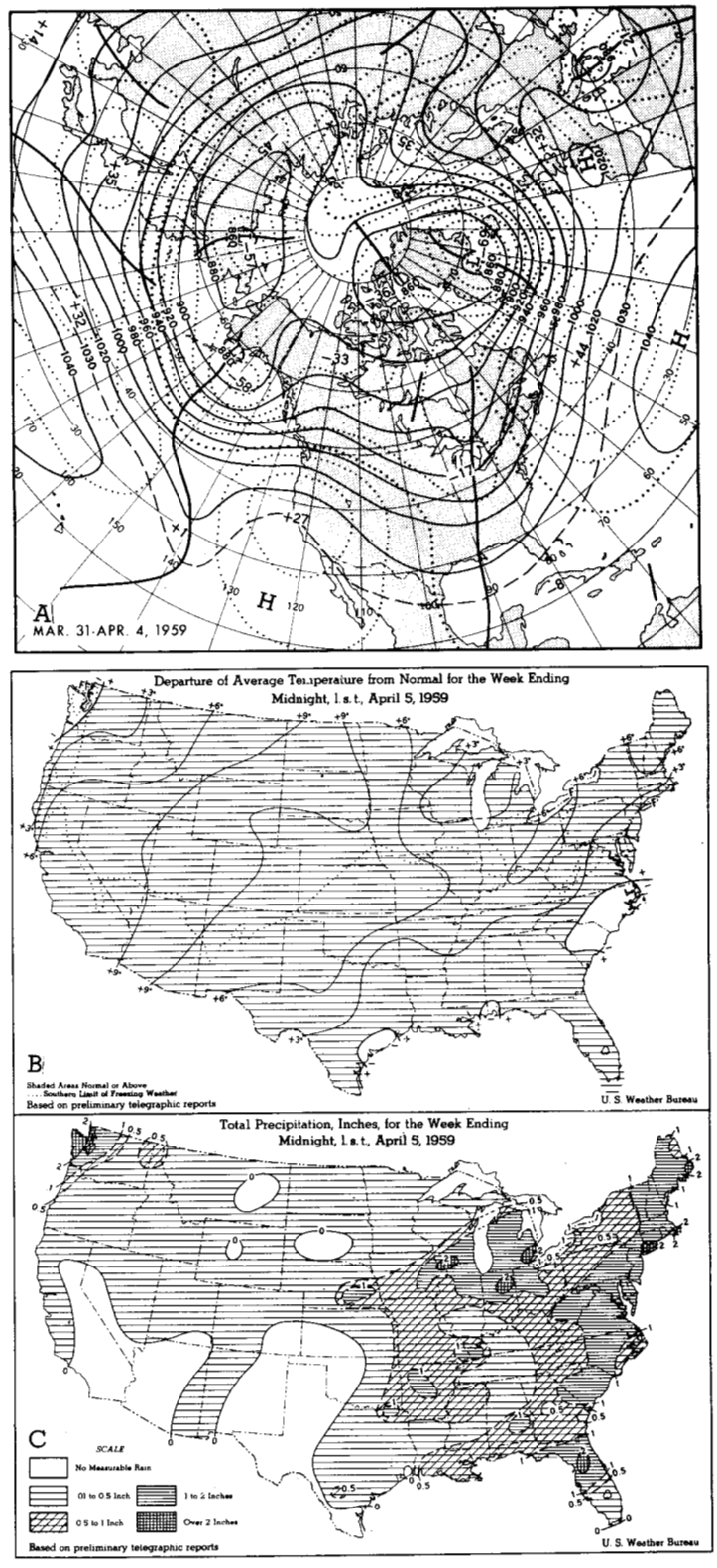

FIGURE 7.—(A) 5-day mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for March 31–April 4, 1959. (B) Departure of average temperature from normal (° F.), and (C) total precipitation (inches) for week ending April 5, 1959. (B and C from *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 14, April 6, 1959.)

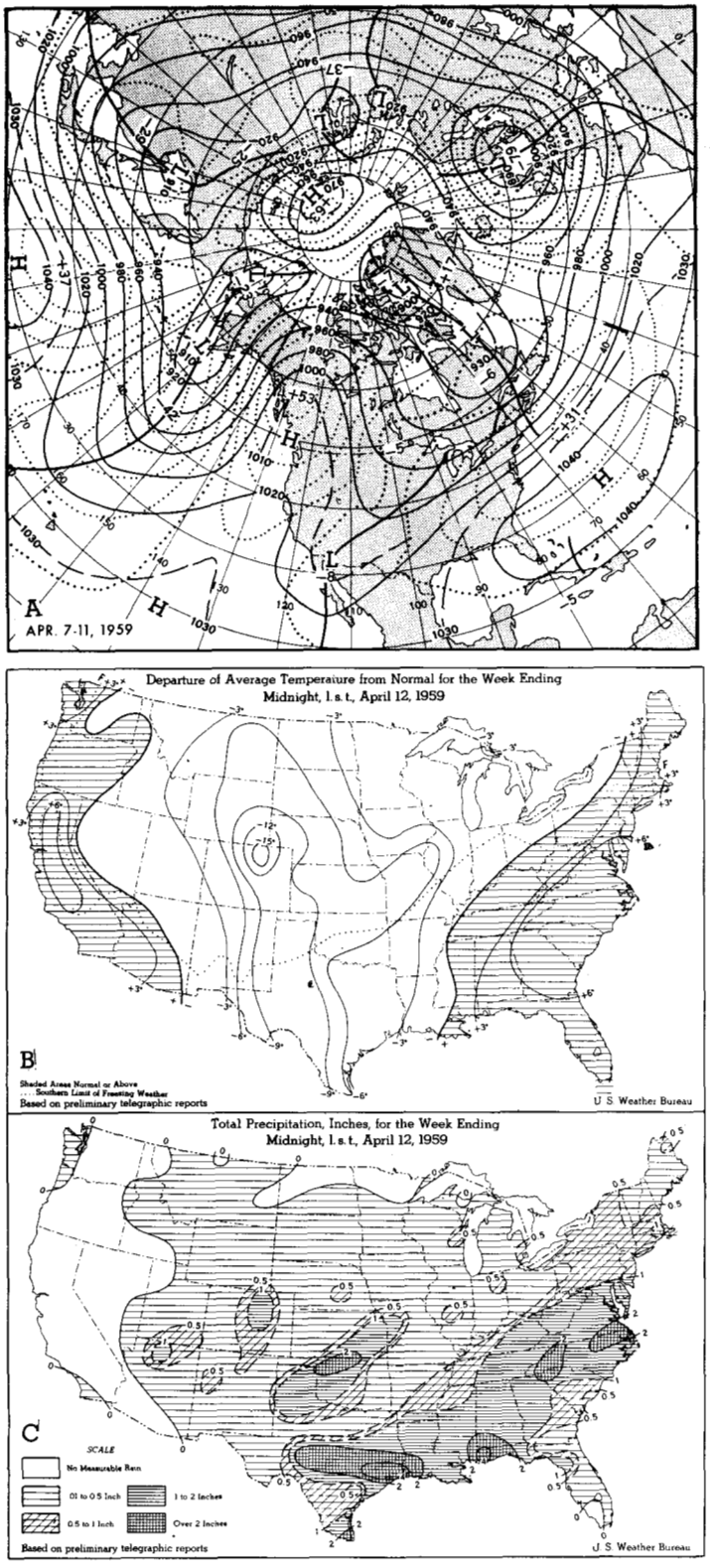

FIGURE 8.—(A) 5-day mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for April 7–11, 1959. (B) Departure of average temperature from normal (° F.), and (C) total precipitation (inches) for week ending April 12, 1959. (B and C from *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 15, April 13, 1959.)

more meridional flow pattern. The strong resemblance between the 5-day mean 700-mb. chart for the first week (fig. 7A) and the mean 700-mb. chart for the month (fig. 1) is noteworthy.

Unseasonably warm weather accompanied this high index circulation over nearly the entire United States (fig. 7B). Mild Pacific air masses, warmed by foehn action in the Rocky Mountains, dominated the country and resulted in record or near-record daily maximum temperatures throughout much of the northern and central Rocky Mountain States. For instance, Salt Lake City, Utah, reported a record 82° F. on April 5, while Pueblo, Colo., with 83° F. on the 2d, equaled its previous April record.

Precipitation during the first week was confined mostly to the extreme Northwest and the area from the middle and lower Mississippi Valley eastward (fig. 7C). Most of the latter precipitation was associated with the deep trough in the Ohio Valley (fig. 7A) and fell as a deepening storm moved northeastward from the lower Great Plains (chart X in [5]). Tornadoes on the 2d caused some loss of life and extensive damage in northeastern Texas.

WEEK ENDING APRIL 12

Gradual amplification of the circulation pattern occured during the second week as the westerlies diminished to more normal values (fig. 6). In the mid-Pacific a stronger than normal ridge appeared, while farther east the mean trough of the previous week deepened while remaining nearly stationary (figs. 7A and 8A). Greatest changes occurred in North America, where strong ridging and a large area of positive height anomaly developed along the Pacific Coast (fig. 8A). At the same time the trough in eastern North America sheared, the higher latitude portion moving eastward, while the low-latitude portion retrograded and redeveloped in the Southwest. Blocking began to appear in the North Atlantic as an intense cyclonic center of action shifted from the eastern Greenland coast to the North Sea, thus replacing the strong ridge of the week before (figs. 7A and 8A). This rapid change in circulation was accompanied by an equally sharp change in weather throughout western Europe—from sunny and pleasant to cold and stormy. Blocking also appeared in the polar regions in the form of a high pressure area with 700-mb. heights as much as 630 feet above normal.

In the United States the change in circulation brought a rapid return to winter weather over much of the Nation. Stronger than normal northerly flow (fig. 8A) deployed very cold polar air into the United States, where temperatures for the week averaged well below normal from the Rocky Mountain States to the Ohio Valley—as much as 15° F. below normal at Denver, Colo. (fig. 8B). The cold was ushered in on the heels of a deep Alberta-type disturbance whose strong winds created severe dust storms

in the Dakotas, Minnesota, and Wisconsin on the 6th and 7th. Many new daily minimum temperature records were established by the abnormal cold in the northern and central Rockies, where only a few days before record warmth had prevailed. Some of these records were (in °F.): 12° at Helena, Mont., on the 9th; 7° at Denver, Colo., on the 10th and 12th; and 6° at Pueblo, Colo., on the 10th. In addition, a temperature of −3°F. at Cheyenne, Wyo., on the 12th was the coldest ever observed there so late in the season. The Far West and the East, where 700-mb. heights were above normal (fig. 8A), continued warm (fig. 8B). The period of greatest warmth in the East, from the 7th to 9th, saw numerous daily maximum temperature records established from Kentucky to southern New England. Baltimore, Md., reported the highest temperature, 92° F., on the 9th.

Precipitation was mostly moderate from Texas northeastward, with little or none over the Far West and northern Great Plains (fig. 8C). Snows were frequent over the Rocky Mountains and extended from the Texas Panhandle to the western Great Lakes. Over a foot of snow fell at the higher elevations in Wyoming and Colorado. Rains were rather persistent in Texas, with heaviest amounts along the upper coast (fig. 8C). The gradual eastward push of the cold air was accompanied by up to 6 inches of snow in parts of West Virginia, Maryland, and Pennsylvania on the 12th. The 6-inch fall at Charleston, W. Va., was the greatest snowfall ever recorded there in April.

This precipitation pattern was the result mostly of overrunning of cold polar air by warmer, more moist, tropical air in southwest flow aloft (fig. 8A). At sea level, high pressure dominated the North American continent, with easterly winds prevailing across most of the United States. The polar front lay in a nearly stationary position from the Middle Atlantic States to the western Gulf of Mexico for nearly the entire week.

WEEK ENDING APRIL 19

The westerlies continued to diminish, with their average strength below normal during this period (fig. 6). At 700 mb. the planetary circulation pattern assumed many of the characteristics commonly associated with a low zonal index. These include a relatively short wave spacing between trough-ridge systems, amplification, and increased cellular nature of the pattern (fig. 9A). The latter feature, which also characterizes blocking, is further illustrated by the 700-mb. height anomaly field. Note (fig. 9A) the preponderance of positive anomaly at higher latitudes and negative anomaly at lower latitudes over much of the Western Hemisphere.

The trough near the Asiatic coast moved eastward during the week, while retrogression of the ridge in western North America to the Gulf of Alaska cut off the eastern Pacific trough and limited it to a deep system

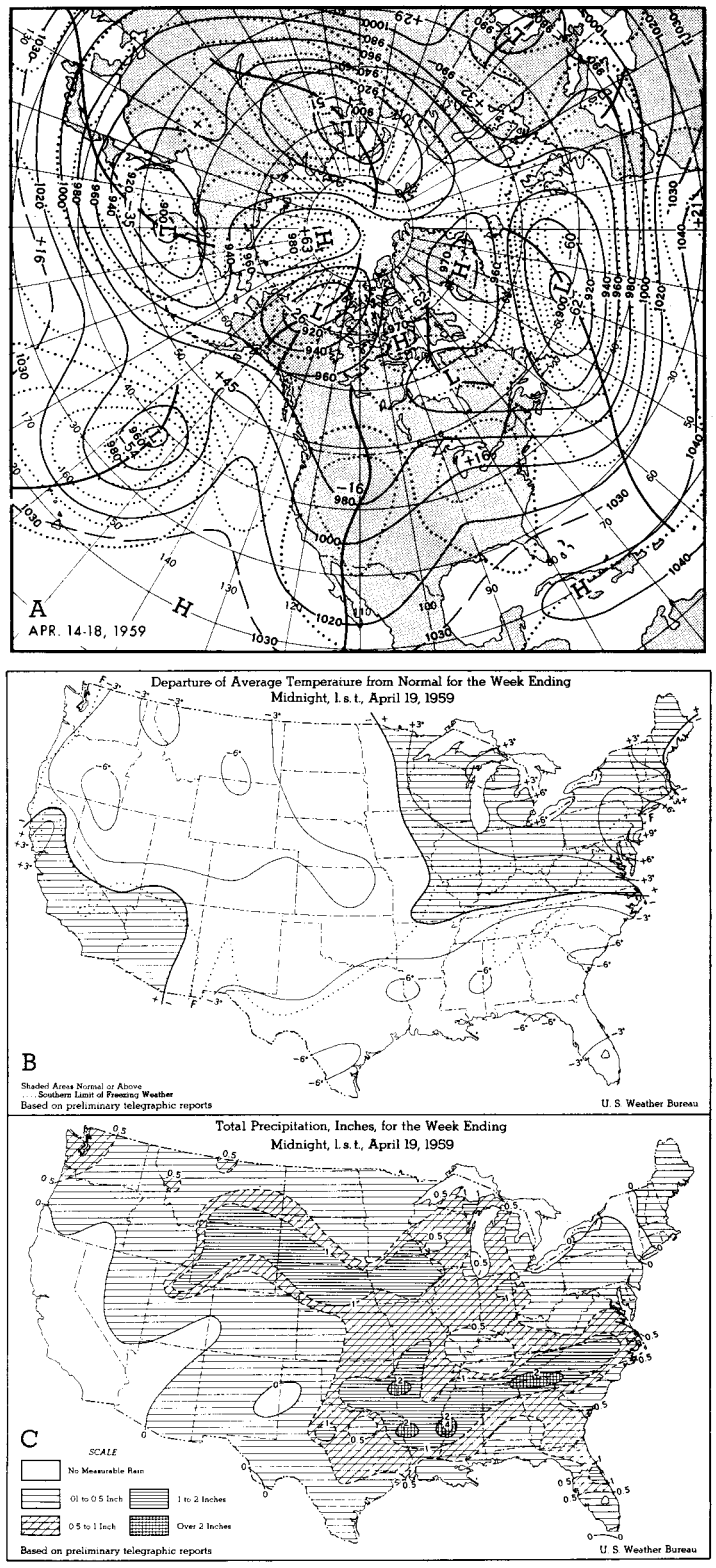

FIGURE 9.—(A) 5-day mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for April 14–18, 1959. (B) Departure of average temperature from normal (° F.), and (C) total precipitation (inches) for week ending April 19, 1959. (B and C from *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 16, April 20, 1959.)

at lower latitudes (fig. 9A). As a consequence, retrogression also occurred in North America, where a nearly-full-latitude trough appeared in the West, while ridging over the East replaced a strong confluence zone. As blocking spread westward and southward from its position over polar regions the previous week, it became entrenched from the Davis Strait to Europe (figs. 8A and 9A) and suppressed the fast westerly belt over the Atlantic and southern Europe.

Temperatures in the United States remained unseasonably cool during the third week over all but the Far Southwest and Northeast (fig. 9B). The cool weather in the West was related to northwesterly flow aloft along the Pacific coast and below normal heights (fig. 9A). In the Gulf States, where heights were close to normal, the below-normal temperatures accompanied a very cold anticyclone which moved from Texas slowly eastward (chart IX in [5]). The warmth in the Northeast can be attributed to the stronger than normal mean ridge (fig. 9A).

Precipitation was generally heavy from Wyoming to Iowa and from Oklahoma to North Carolina (fig. 9C). Elsewhere amounts were mostly light to moderate, except in California and portions of the western Plateau where no measurable amounts fell. Snow fell once again from the Central Rockies to the lower Great Lakes late in the week, with a total fall of 15 inches at Lander, Wyo. A series of waves developing along a cold front as it moved slowly eastward and southeastward across the Nation was responsible for much of the precipitation during the week.

WEEK ENDING APRIL 26

The zonal index reached a minimum value of 6.5 m.p.s. between the third and fourth weeks, and then, although remaining below normal, began to recover (fig. 6). The principal seat of blocking spread from the Davis Strait to the Pacific with characteristic pronounced meridional flow pattern, strong ridges, and cut-off lower latitude Lows (fig. 10A). As blocking relaxed in Canada, the westerlies increased across North America, the trough in the southwestern United States moved rapidly eastward across the country and amalgamated with the trough in the western Atlantic, while the ridge off the Pacific coast also moved eastward to the Rocky Mountains (figs. 9A and 10A).

Subnormal temperatures predominated over most of the United States (fig. 10B) as stronger than normal northwesterly flow in western Canada (fig. 10A) continued to deploy cold Canadian air masses into the country. However, eastward motion of the trough-ridge system in the United States was related to a warming trend which gradually spread eastward. This is readily seen by comparing figure 9B with figure 10B. Note the growth of the area of above normal temperatures in the Far West, associated with ridging and above normal heights, and the diminu-

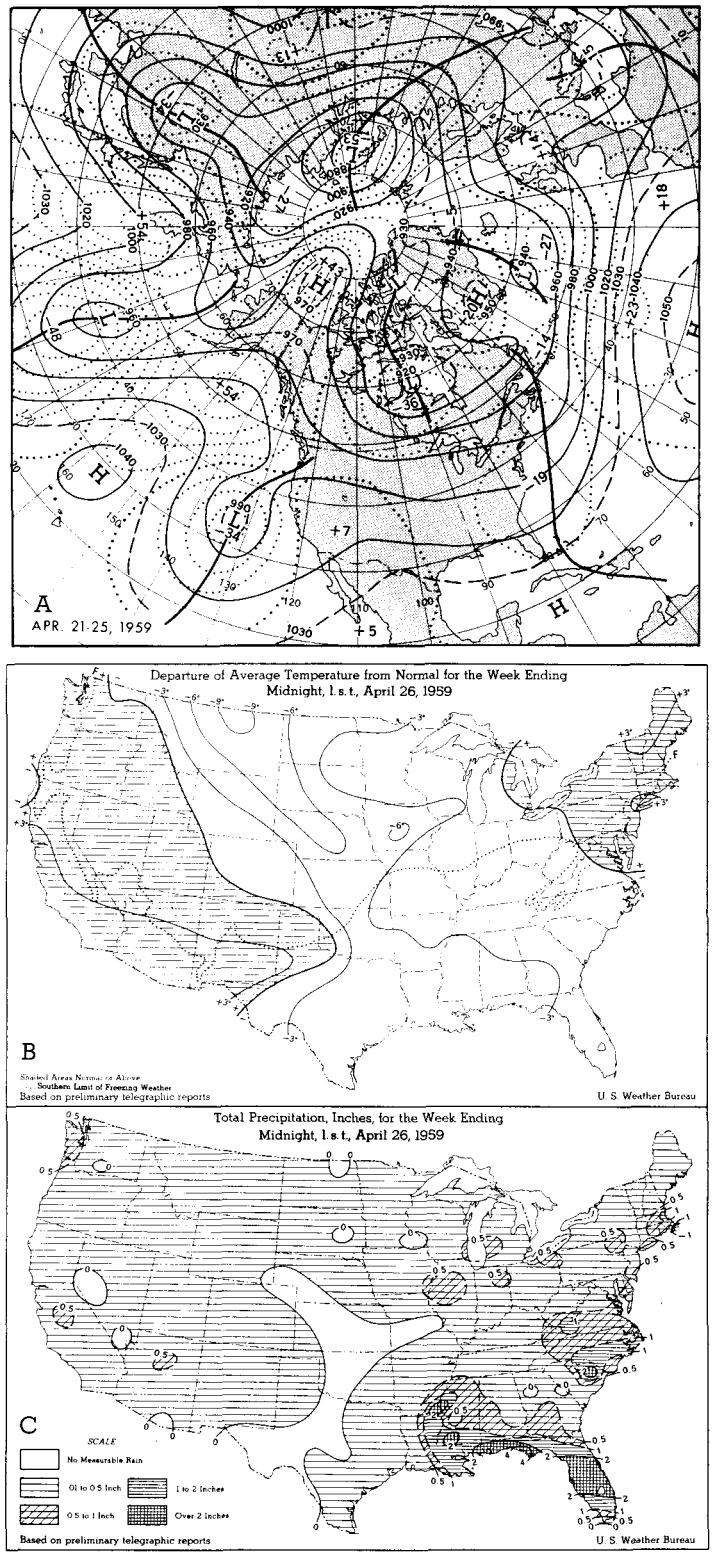

FIGURE 10.—(A) 5-day mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for April 21–25, 1959. (B) Departure of average temperature from normal (° F.), and (C) total precipitation (inches) for week ending April 26, 1959. (B and C from *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 17, April 27, 1959.)

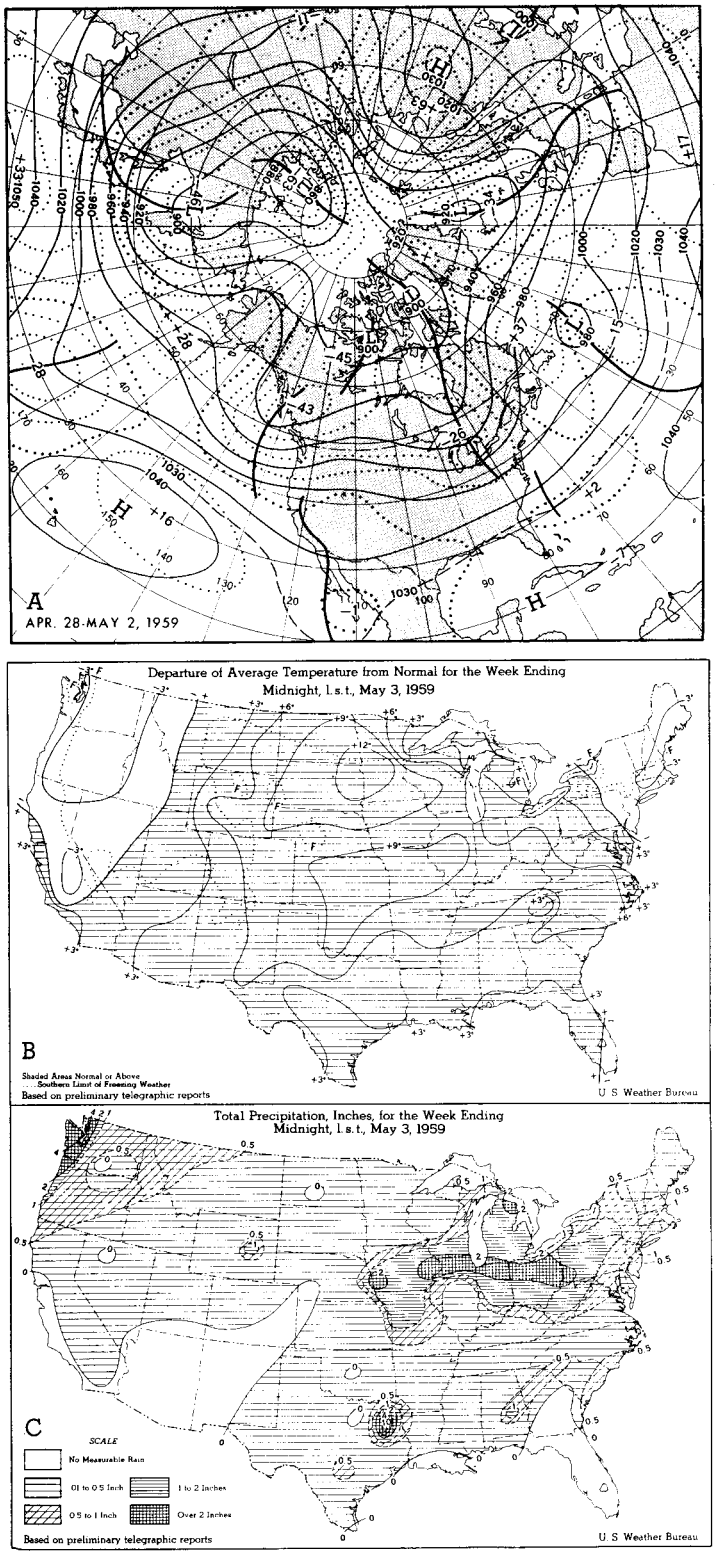

FIGURE 11.—(A) 5-day mean 700-mb. contours (solid) and height departures from normal (dotted) (both in tens of feet) for April 28–May 2, 1959. (B) Departure of average temperature from normal (° F.), and (C) total precipitation (inches) for week ending May 3, 1959. (B and C from *Weekly Weather and Crop Bulletin, National Summary*, vol. XLVI, No. 18, May 4, 1959.)

tion of the area of above normal temperature in the Northeast, related to the decrease in 700-mb. height (figs. 9A and 10A). At Roswell, N. Mex., the temperature reached 97° F. on the 25th, an April record.

The precipitation pattern also tended to move eastward from the preceding week (figs. 9C and 10C). Heaviest amounts fell in the eastern Gulf States and portions of the Atlantic Coastal States. Most of this occurred early in the week in connection with a cold front and cyclonically curved contours at 700 mb. (fig. 10A). As the west coast ridge moved inland and the eastern Pacific trough approached the coast, precipitation broke out in California, southern Oregon, and western Nevada. Rain on the 25th at Burbank, Calif., ended a period of 62 consecutive days without measurable precipitation.

WEEK ENDING MAY 3

A peak value of 9.6 m.p.s. was reached by the zonal index between the fourth and fifth weeks, thus completing the cycle which began at the beginning of April (fig. 6). This increase in the mid-tropospheric zonal circulation was manifested at the 700-mb. level by eastward motion of nearly all the mean trough and ridge systems (figs. 10A and 11A).

The warming trend in evidence in the West the previous week overspread almost the entire country, with only the Northwest and extreme Northeast experiencing below normal temperatures (fig. 11B). Greatest departures were reported in the middle of the Nation, where a large anomaly area greater than +9° F. was observed. Heavy precipitation, the result of strong onshore cyclonic flow, returned to the Pacific Northwest (fig. 11C), while heavy amounts were also reported from Iowa to southern New England as a by-product of the trough over the Great Lakes (fig. 11A).

April came to a close with the westerlies decreasing rapidly, and as May began they were once again well below normal (fig. 6).

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